Market Sector:
FUSION ENERGY

Technology Theme:
MATERIALS TECHNOLOGY – COMPONENT MANUFACTURING TECHNOLOGY

NEAR NET SHAPE MANUFACTURING OF INTERNAL COOLING CHANNELS IN A COPPER ALLOY HEAT SINK

Experimental trials were carried out to create internal cooling channels within a CuCrZr heat sink using the powder hot isostatic pressing (HIP) process.

316L cooling channels within a CuCrZr heat sink (cross-sectioned)

Hollow cooling channels within a CuCrZr heatsink (not cross-sectioned)

Dimensions of the demonstrator are: 10 x 10 x 10 cm3

> Through the completion of this feasibility study, MTC experts have demonstrated the process know-how, materials knowledge, and experience to support the fusion energy industry for advanced heat sink development.
>
> **Yijun Liu, Chief Metallurgist - Materials Technology, MTC**

THE CHALLENGE

Plasma facing components (PFCs) within a fusion reactor are subject to extremely high heat fluxes, high-energy particle bombardment, and chemical reaction. Heat sink materials must be able to handle high temperatures and effectively dissipate heat, as well as withstanding the harsh corrosive conditions and maintain structural integrity. The heat sink material must also be compatible with the plasma and not introduce any impurities or other contaminants that could affect the fusion process. In addition to the material requirements, the design and method of manufacture of the heat sink is critical and the creation of cooling channels presents a huge challenge due to the intricate and complex geometries involved and the need for high precision.

MTC'S SOLUTION

- The MTC carried out a review of the potential materials and manufacturing methods for overcoming the challenges and also engaged with contacts in the fusion sector.
- The powder HIP process was used to consolidate Copper Chromium Zirconium (CuCrZr) powder directly with stainless steel or CuCrZr cooling channels.
- Nickel was used as the interlayer between the CuCrZr alloy and the stainless steel to provide good integrity with tensile testing being conducted to evaluate the interface quality.

THE OUTCOME

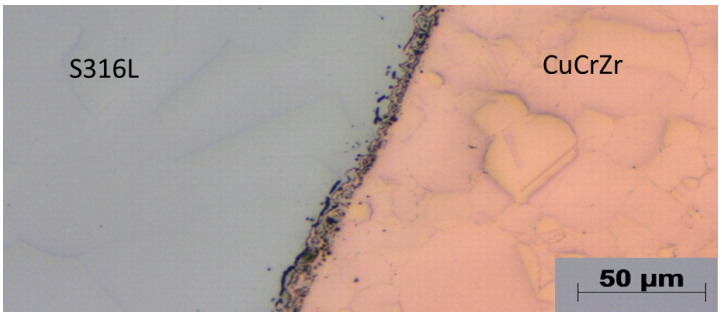
- The study demonstrated the feasibility of creating internal cooling channels within a heat sink in a single step process.
- Two types of cooling channels were trialled: stainless steel embedded channels with 316L pipes, and hollow channels formed by a mild steel canister being leached away following the HIP process.
- The initial study demonstrated the nickel interlayer produced a good quality bond between 316L and CuCrZr. Tensile properties of the 316L-CuCrZr bond were stronger than the CuCrZr matrix phase.

BENEFITS TO THE CLIENT

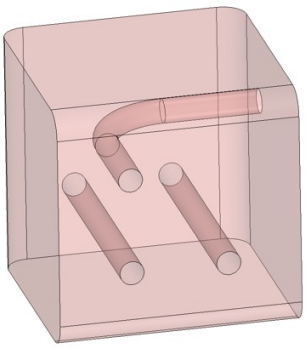
- HIP creates a homogeneous microstructure which can improve thermal conductivity and heat transfer, resulting in improved performance and reliability.
- Powder HIP offers greater design flexibility and the possibility of creating complex shapes with internal features.
- The HIP process can reduce manufacturing time, waste and material costs through near net shape manufacture and multi-material joining.

> Utilising the expertise and advanced manufacturing technologies available at the MTC our engineers have demonstrated the feasibility of manufacturing complex components suitable for extreme environments. We hope to further develop these technologies with our partners for broader implementation.
>
> **Matt Thomas, Chief Engineer – Component Manufacturing Technologies, MTC**

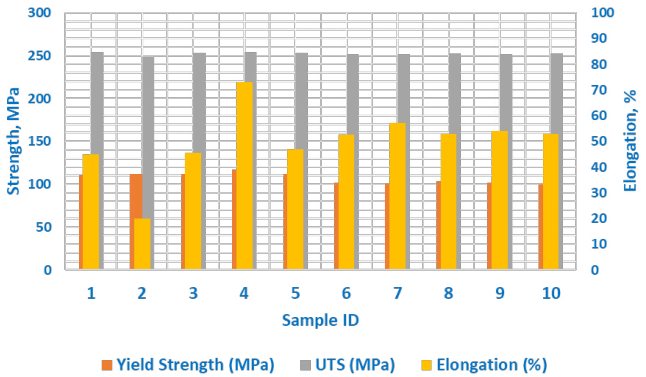
Tensile samples fractured in the gauge section of the CuCrZr indicating good bonding quality of the 316L/CuCrZr interface



Uniform mixture of copper with iron at the interface due to diffusion of copper into the iron phase



Configuration of the cooling channels within the heat sink



Tensile properties of the 316L-CuCrZr interface (Sample ID 1-5) and matrix CuCrZr (Sample ID 6-10)

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